

# PATENT SPECIFICATION

DRAWINGS ATTACHED

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## COMPLETE SPECIFICATION

### Radar-Reflective Towed Target

- We, DEL MAR ENGINEERING LABORATORIES, a corporation organised and existing under the laws of the State of California, United States of America, of 6901, Imperial Highway, Los Angeles, California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
- This invention relates to an aerial towed target to simulate the radar reflectivity of a military aerial target, such as an aircraft, for practice in tracking and intercepting such a military target. The invention relates particularly to a tow target of the type having a hollow bulbous streamlined body of revolution which is continuously rotated on its longitudinal axis in the course of flight.
- A major problem to which the invention is directed is to achieve the type of radar reflectivity that characterises an aircraft, such as a large bomber. The pattern of the power of the radar signals reflected back from a B—26 bomber is shown on page 76 of "Radar System Engineering" by Ridenour (McGraw-Hill) and is characterised by relatively narrow peaks extending around the azimuth, the peaks being so closely spaced as to be equivalent, in effect, to substantially uniform strength of the reflected signals in all directions. The numerous relatively narrow high amplitude peaks are caused by constructive and destructive interference of waves reflected from different surfaces. The destructive interference results in cancellation and the constructive interference results in the peaks.
- A second problem to which the invention is directed is to provide the desired radar reflection pattern and at the same time to provide storage space in the tow target for various kinds of tow target equipment. The equipment may include such items as radio components, a power supply unit and means for firing flares at the trailing end of the tow target. Such equipment is heavy in comparison with the weight of the tow target body so that careful consideration must be given to the location of the equipment to avoid intolerable shift in the location of the centre of gravity of the loaded tow target.
- With reference to the first problem, the range at which a radar reflective target can be detected by a given radar detector system in a given direction from the tow target depends on the radar cross section, i.e., the radar reflective area that can be "seen" from the detector, and varies with the fourth root of the radar cross section. The radar cross section varies with the aperture area. In other words, large corner reflectors are required for detection of the tow target at substantial distances and the problem is to get corner reflectors of the largest possible aperture area facing in all directions and occupying a minimum volume of the general configuration of a tow target. The pattern of radar reflectivity can be represented by plotting the fourth root of the radar cross section of the tow target for the different directions over a range of 360°. This first problem is met if such a diagram reveals that the tow target effectively reflects radar signals around the whole azimuth with no significant null zones.
- According to the present invention there is provided a radar-reflective towed target having a hollow, bulbous, streamlined body adapted to rotate continuously in flight about its longitudinal axis, wherein forward end, rearward end and intermediate reflector assemblies are provided within the body, the forward and rearward end assemblies comprising forwardly and rearwardly directed corner assemblies respectively and the intermediate assembly comprising four reflecting surfaces 90° apart extending longitudinally of the said body and transverse reflecting surfaces at the two ends of the said four surfaces forming first and second sets of circumferentially-spaced corner reflectors with axes

of symmetry inclined forwardly and rearwardly respectively at angles to the said longitudinal axis.

The forwardly and rearwardly facing corner reflectors produce corresponding forward and rearward lobes of substantial angular dimension on the plotted diagram. The intermediate assembly comprises longitudinal radial reflector surfaces 90° apart in combination with transverse surfaces at the opposite ends thereof preferably at 90° thereto. These longitudinal and transverse surfaces form two circumferential series of corner reflectors, the corner reflectors of one series having their axes of symmetry inclined forward approximately 45° from the longitudinal axis of the tow target, the corner reflectors of the other series having their axes of symmetry inclined approximately 45° rearward. Each corner reflector has three plane surfaces at 90° from each other intersecting at a common point and the axis of symmetry is a line through the intersection point at the same angle to all three surfaces, the angle being 45°. These two series of inclined corner reflectors produce four diagonal lobes when the tow target rotates on its axis, each of the four lobes being of substantial angular dimension and being of a radial dimension comparable to the radial dimensions of the previously mentioned forward and rearward lobes.

The longitudinal reflector surfaces of the intermediate assembly also produce high amplitude opposite lateral lobes perpendicular to the tow target axis and while these opposite lateral lobes are much narrower than the forward, rearward and intermediate lobes, they do complete an azimuth pattern that may be adequate for some tow target exercises. It is preferred however to include additional corner reflectors to produce opposite lateral lobes of substantial angular magnitude to fill out the azimuth pattern and to approach more closely the reflectivity behaviour of a large bomber.

These additional corner reflectors can be incorporated in either the forward reflector assembly or in the rearward reflector assembly, and can comprise two circumferential series of corner reflectors. The axes of symmetry of the corner reflectors of one of these additional series are inclined forward at substantially less than 45° from a plane perpendicular to the axis of the tow target body and the axes of symmetry of the other series of corner reflectors are inclined rearward at substantially less than 45° from the perpendicular plane. With this arrangement, the angular ranges of reflection of the two series overlap to produce the desired relatively broad lateral lobes of the diagram.

The described arrangement of radar reflecting surfaces takes full advantage of the rotation of the tow target to produce a pattern symmetrical about the longitudinal axis of reflection that sufficiently approaches uni-

formity in all directions to serve the purpose of the invention. The pattern is a pulsating pattern by reason of the rotation of the tow target and, therefore, the lobes of the diagram represent average values. The frequency of the pulsations is high enough to keep the radar guidance system of a missile "locked" on the tow target, any null periods or low periods of energy of radar reflection being so momentary as to be insignificant.

With reference to null or low energy regions in the pattern of radar reflectivity, it is to be noted that where the lobes of the pattern overlap in the low energy regions, the overlapping reflected signals interfere to add and cancel and the additive signals produce narrow relatively high amplitude peaks.

The second problem of providing space in a tow target body for the tow target equipment must take into consideration not only the effect of the equipment on the centre of gravity of the loaded tow target, but must also take into consideration the necessity for avoiding undue masking of the radar reflecting surfaces by the equipment.

An important subsidiary feature of the invention is that the described arrangement of three reflector assemblies makes it possible to provide a completely satisfactory equipment compartment simply by separating either the forward assembly or the rearward assembly or both from the intermediate assembly. Both of the forward and rearward reflector assemblies can provide additional space for relatively small pieces of equipment, if such additional space is required. As will be apparent, when the equipment is located on the tow target in this manner, it does not mask any of the essential radar reflector surfaces.

The invention will now be described by way of example with reference to the accompanying drawings in which:—

Figure 1 is a view partly in side elevation and partly in section, showing a towed target embodying the invention;

Figure 2 is a perspective view of the radar reflector structure that is enclosed in the body of the tow target shown in Figure 1,

Figure 3 is a transverse section taken as indicated by the line 3—3 of Figure 2 to show the construction of the intermediate radar reflector assembly,

Figure 4 is an end elevation of the reflector structure viewed as indicated by the arrow 4 in Figure 2;

Figure 5 is an elevation of the reflector structure viewed from the opposite end as indicated by the arrow 5 in Figure 2,

Figure 6 is a view partly in side elevation and partly in section showing a second towed target embodying the invention,

Figure 7 is a similar view of a third towed target embodying the invention,

Figure 8 is a diagram that approximates the pattern of the power of radar signals re-

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flected to their sources from a bomber, and

Figure 9 is a diagram representing the pattern of radar reflection of the towed target embodying the present invention, the diagram showing the fourth root of the radar cross section of the towed target plotted for the different directions of viewing over a range of 360° in azimuth.

Figure 1, illustrating the first embodiment of the invention, shows a towed target having a bulbous streamlined body of revolution, generally designated 10, which is connected by a swivel fitting 12 to a tow cable 13, the purpose of the swivel fitting being to permit the towed target to rotate on its longitudinal axis without twisting the cable. In the construction shown, the swivel fitting 12 is connected to a conical lead body 14 in the nose of the tow target, which lead body is a counterweight to ensure that the centre of gravity of the towed target is located sufficiently forward.

The towed target body 10 is equipped with four stabilizing tail fins 15 having angled or bent tips 16 which react to the air stream and serve as aerodynamic means to cause the towed target to rotate about its longitudinal axis as it is drawn through the air. In a typical flight below sonic speeds, the towed target may rotate, for example, at a rate of 100 to 300 rpm. This particular tow target is adapted to carry flares at its trailing end to be ignited under remote control. For this purpose, the body 10 is provided with a series of four streamlined casings 18 to receive flares, each casing being mounted between a pair of stabilising fins 15.

The target body 10 is hollow and may be of any suitable construction. In this instance, the body comprises a series of thin-walled sections, each of which is made of paper pulp moulded under heat and pressure. The moulded paper sections are impregnated with a suitable waterproofing agent which not only makes the body material waterproof, but also provides the tow target with a smooth exterior surface.

In the construction shown, the body 10 comprises a moulded nose section 10a, two central sections 10b and 10c, and a tail section 10d. These sections are interconnected by overlapping joints, as shown, with the outer surface of the tow target smooth at each joint.

The structure for reflecting radar signals comprises a forward radar reflector assembly, generally designated A, an intermediate radar reflector assembly, generally designated B, and a rearward radar reflector assembly, generally designated C. The required space for the tow target equipment that must be carried by the body 10 is provided by spacing the forward assembly A and the intermediate assembly B a suitable distance apart to form an equipment compartment 20. In this instance, the equip-

ment includes a power pack 22 and two sections of a radio receiver 24. This equipment is mounted on a sheet metal bulkhead 25 which forms the forward wall of the equipment compartment 20 and which is formed with a circumferential flange 26 to reinforce the body shell.

The forward radar reflector assembly A comprises three panels 28, 30 and 32, which are in planes that intersect at 90° with each other at a common point located substantially on the longitudinal axis of the tow target body. To permit the three panels to intersect in the required manner, the panels are cut into sections that meet along lines of intersection of the planes and some of the sections can be slotted to straddle other sections along lines of intersection of the planes.

The three panels 28, 30 and 32 may be made of any suitable material to provide metal reflecting surfaces on the opposite faces of the panels. In the present construction, the panels comprise plates of foamed plastic, such as foamed cellulose acetate or foamed polystyrene, each plate having a layer of metal foil, such as aluminium foil, bonded to each of its faces. The three intersecting panels 28, 30 and 32 are cut to a generally elliptical configuration to meet with the surrounding body shell of the tow target and are bonded to the body shell so that the shell reinforces the reflector panels, and the reflector panels in turn reinforce the shell.

The three panels 28, 30 and 32 form a forwardly directed corner reflector, generally designated 34, at the front end of the tow target, this corner reflector having the usual configuration in which three reflecting surfaces at 90° from each other meet at a common point. The axis of symmetry of this forward corner reflector substantially coincides with the longitudinal axis of the tow target.

In the construction shown, the three reflector panels 28, 30 and 32 extend rearward of their common point of intersection on the axis of the tow target and are backed at their rearward edges against the previously mentioned sheet metal bulkhead 25. The extension of the three panels 28, 30 and 32 rearward from their point of common intersection results in the formation of six additional corner reflectors comprising a first circumferential series of three corner reflectors 35 having their axes of symmetry inclined at less than 45° forward from a plane perpendicular to the axis of the tow target, and a second circumferential series of three corner reflectors 36 having their axes of symmetry inclined at less than 45° in the opposite rearward direction from the perpendicular plane.

Figure 1 shows how the panels 28, 30 and 32 form two of the forwardly inclined corner reflectors 35 and one of the rearwardly inclined reflectors 36. Figure 2 shows in perspective how the three panels form one of the

forwardly inclined corner reflectors 35 and two of the rearwardly inclined corner reflectors 36. It is apparent from an inspection of these two figures that the two circumferential series of corner reflectors 35 and 36 are staggered, the forwardly inclined corner reflectors alternating with the rearwardly inclined corner reflectors.

The intermediate reflector assembly B comprises four longitudinal panels 38 in combination with two transverse panels 40 and 42 at the opposite ends thereof. These panels may be of the previously described construction comprising plates of foamed plastic with foil bonded to the opposite surfaces of the plates. The longitudinal panels 38 meet along the longitudinal axis of the tow target and are positioned at 90° angles from each other. The longitudinal panels 38 meet the forward transverse panel 40 to form a circumferential series of four corner reflectors 44 that have their axes of symmetry inclined rearwardly at angles of approximately 45° from the longitudinal axis of the tow target body. In like manner, the four longitudinal panels 38 meet the rearward transverse panel 42 to form there-with a circumferential series of four corner reflectors 45 having their axes of symmetry inclined forwardly at approximately 45° from the longitudinal axis of the tow target body. The length of the four longitudinal panels should be at least approximately twice their width or radial dimension to prevent partial masking of the two sets of corner reflectors 44 and 45.

Figure 1 shows how a pair of dipole antennae for the radio receiver 24 can be mounted in the region of the intermediate radar reflector assembly B. Each dipole antenna 46 comprises two wires bent to the configuration shown, and extending into the longitudinal space formed by a pair of the longitudinal panels 38. These antenna wires being very small in relation to the wave length of the radar will have little or no effect on the radar reflectivity. Antennae can also be placed in the nose or tail if required.

The rearward radar reflector assembly C comprises three foil-covered foamed plastic panels 48, 50 and 52 positioned at 90° from each other and meeting at a common point on the longitudinal axis of the tow target, this point being adjacent the rearward panel 42 of the intermediate radar reflector assembly B. This arrangement forms a rearwardly directed corner reflector 54 having its axis of symmetry substantially coinciding with the longitudinal axis of the tow target body. Here again the outer edges of the three panels 48, 50 and 52 are of generally elliptical configuration to meet the body shell of the tow target, the three panels being bonded to the body shell to reinforce the body shell and to be reinforced by the body shell. Thus the rearward corner

reflector 54 is of circular configuration when viewed along the axis of the tow target, as may be seen in Figure 5, just as the corner reflector 34 at the forward corner reflector 34 is circular in configuration when viewed along the axis of the tow target, as may be seen in Figure 4.

Figure 8 is a circular graph showing the strength of the radar signals reflected back from a bomber. It is apparent that the strength of the reflected signals is substantial in all directions of the azimuth. Figure 9 shows how the pattern of reflection of radar signals back to their sources produced by the described tow target also provides reflected signals of adequate strength over a range of 360°.

In the general radar equation, the range of detection appears as a fourth power while the radar cross section appears as a first power. Thus the actual range of detection is proportional to the fourth root of the radar cross section. In Figure 9, the fourth root of the radar cross section is plotted for the different directions of viewing the tow target. The curves in Figure 9 are calculated estimates based on both theoretical analysis and actual test data. It is necessary to show average values because the target is rotated. The average values shown in Figure 9 are conservative since the peak values are almost always at least twice the average values.

In Figure 9, the forward lobe 34a of the radar reflection pattern is produced by the forward corner reflector 34 of the forward radar reflector assembly A. In like manner, the rearward lobe 54a is produced by the corner reflector 54 which is provided at the rear end of the tow target. The two diagonally forward lobes 45a in Figure 9 are produced by the circumferential series of four corner reflectors 45 of the intermediate radar reflector assembly B. In like manner, the two rearwardly inclined lobes 44a in Figure 9 are produced by the circumferential series of four corner reflectors 44 of the intermediate radar reflector assembly B. In addition, Figure 9 shows two opposite lateral lobes 55 that are relatively narrow but of relatively high amplitude. These lateral lobes are produced not by corner reflectors, but by convergent pairs of the longitudinal panels 38 of the intermediate radar reflector assembly B.

It is apparent from Figure 9 that the six lobes comprising the end lobes 34a and 54a, the pair of diagonal lobes 44a and the pair of diagonal lobes 45a are uniformly distributed around the azimuth and overlap sufficiently at the bases of the lobes to avoid null points. It may be readily appreciated that the six lobes make the tow target capable of detection in all directions of the azimuth. Since the tow target is rotating, the azimuth pattern shown in Figure 9 is a section of a pattern that is actually symmetrical about the longitudinal

axis of the target so that the tow target can be detected equally well from above and from below.

With the six lobes supplemented by the two high amplitude narrow lateral lobes 55, the pattern of radar reflection as described to this point is satisfactory for some purposes. In the preferred practice of the invention, however, the reflection pattern is augmented by the two circumferential series of corner reflectors 35 and 36 of the forward radar reflector assembly A. Since the axes of symmetry of these two series of corner reflectors are inclined only slightly in opposite directions from a plane perpendicular to the axis of the tow target, the reflection patterns of the two series overlap to make relatively broad lateral lobes in Figure 9. Each of these lobes has a forward portion 35a which is primarily the result of the three corner reflectors 35 and a rearward portion 36a which is primarily the result of the three corner reflectors 36. With these additional relatively broad lateral lobes, the complete reflection pattern shown in Figure 9 is equivalent to the reflection pattern shown in Figure 8 with respect to the capability of the tow target for detection by radar systems that are designed to track aerial objects and are designed to guide missiles automatically for interception of aerial objects.

In Figure 9 the constructive and destructive interference of the signals in the low energy regions where the lobes overlap result in additional narrow signal peaks 56 which to a useful degree improve the low energy regions and which also simulate the reflectivity of an aircraft.

Figure 6, illustrating the second embodiment of the invention, exemplifies the fact that the radar reflecting structure of the first described embodiment can be reversed end for end in the tow target body 10. Thus in Figure 6, the radar reflector assembly A is in the tail section of the tow target rearward from the intermediate radar reflector assembly B and the third radar reflector assembly C is in the nose section of the body. It is obvious that the second embodiment of the invention will produce the same pattern of reflectivity shown in Figure 9.

Figure 6 further illustrates the fact that a compartment for the tow target equipment can be provided at either end of the intermediate radar reflector assembly B. Figure 6 shows a forward equipment compartment 60 which corresponds to the equipment compartment 20 of the first embodiment of the invention. Figure 6 also shows a rearward equipment compartment 62, the forward wall of which is formed by the intermediate radar reflector assembly B and the rear wall of which is a bulkhead 65. In Figure 6, the broken line rectangle 64 represents equipment in the compartment 62. The three panels of the radar

reflector assembly A back against the bulkhead 65.

Figure 6 further illustrates the fact that both the radar reflector assembly A and the radar reflector assembly C provide additional dead space which can be occupied by equipment. Equipment indicated in broken lines at 66 and 68 is shown mounted on a bulkhead 70 to occupy space in the region of the corner reflector 54, and equipment indicated by the broken lines 72 is mounted on the bulkhead 65 in the region of the radar reflector assembly A.

In some instances, a radar-reflective tow target carries no equipment whatsoever. In such instances, the radar reflector structure shown in Figure 7 can be employed. In Figure 7, the three radar reflector assemblies A, B and C are in the same reversed order as in Figure 6. The bulkhead 65 of Figure 6 is omitted since the radar reflector assembly A backs against the radar reflector assembly B and the bulkhead 70 of Figure 6 is omitted since the radar reflector assembly C also backs directly against the radar reflector assembly B. The structure shown in Figure 7 includes an internal reinforcing band 74 for the body shell, this reinforcing band being made of plastic material or other material that is substantially transparent to radar signals.

#### WHAT WE CLAIM IS:—

1. A radar-reflective towed target having a hollow, bulbous, streamlined body adapted to rotate continuously in flight about its longitudinal axis, wherein forward end, rearward end and intermediate reflector assemblies are provided within the body, the forward and rearward end assemblies comprising forwardly and rearwardly directed corner assemblies respectively and the intermediate assembly comprising four reflecting surfaces 90° apart extending longitudinally of the said body and transverse reflecting surfaces at the two ends of the said four surfaces forming first and second sets of circumferentially spaced corner reflectors with axes of symmetry inclined forwardly and rearwardly respectively at angles to the said longitudinal axis.

2. A towed target according to claim 1, wherein at least one of the end assemblies is spaced from the intermediate assembly to provide a compartment for tow target equipment, without the equipment masking the reflecting surfaces of the reflector assemblies.

3. A towed target according to claim 1 or 2, wherein the body is in a form of a thin-walled shell, the two end reflectors being formed of members with generally elliptical edges joined to the shell so that, in full front or rear end views the forward and rearward end reflectors appear circular in outline.

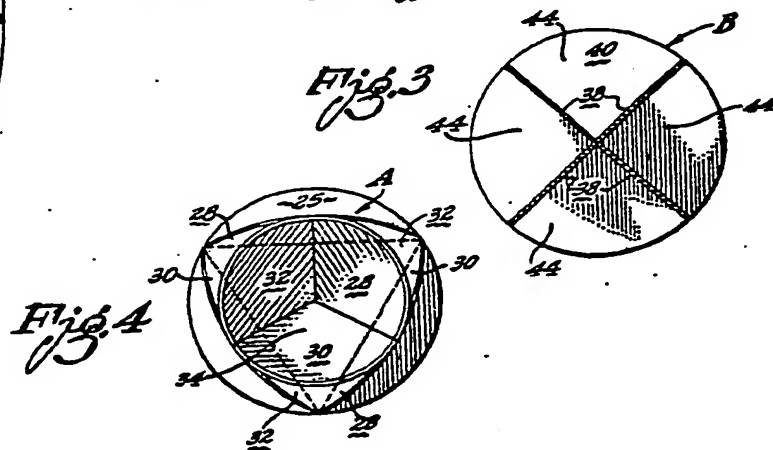
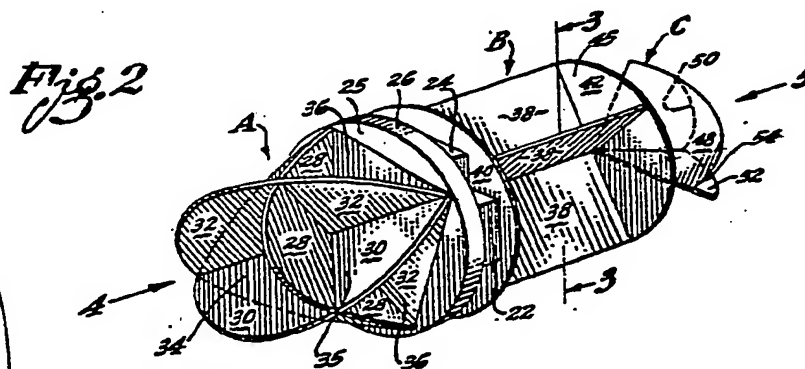
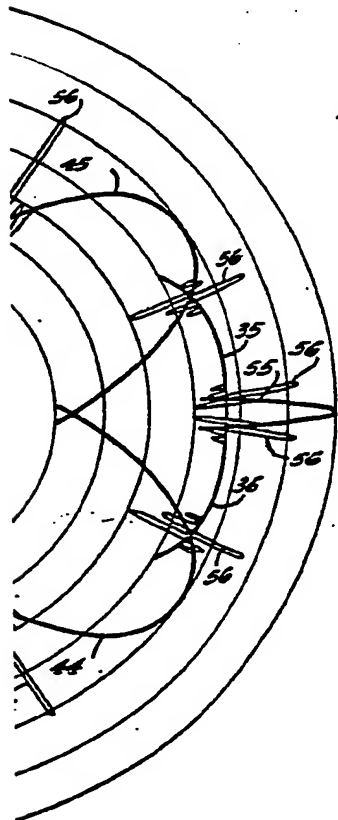
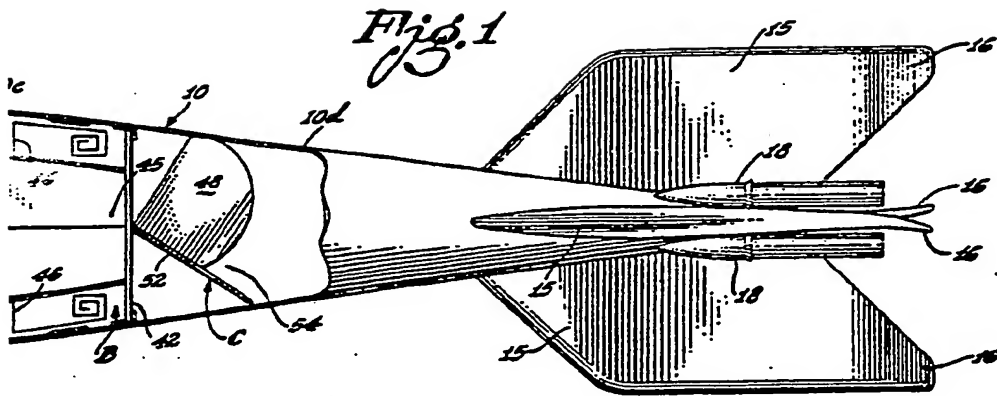
4. A towed target according to claim 1, 2 or 3, wherein at least one of the end assemblies provides a third set of circumferentially-spaced corner reflectors with axes of symmetry

- inclined forwardly at substantially less than 45° from a plane perpendicular to the said longitudinal axis and at least one of the end assemblies provides a fourth set of circumferentially-spaced corner reflectors with axes of symmetry inclined rearwardly at substantially less than 45° from a plane perpendicular to the said longitudinal axis.
- 5 5. A towed target according to claim 4, wherein the third and fourth sets of reflectors are provided by one end assembly.
- 10 6. A towed target according to claim 5, wherein the said one end assembly is provided by three reflector panels intersecting at 90° to each other in a common point substantially on the said longitudinal axis, the panels extending both forwardly and rearwardly of the said point to form a total of six corner reflectors in addition to the rearwardly or forwardly directed corner reflector, the said six comprising two sets of three each constituting the said third and fourth sets respectively and circumferentially staggered relative to each other. 20
7. A radar-reflective towed target substantially as hereinbefore described with reference to and as shown in Figs. 1 to 5 or Fig. 6 or Fig. 7 of the accompanying drawings. 25
- 15 6. A towed target according to claim 5, wherein the said one end assembly is provided by three reflector panels intersecting at 90° to each other in a common point substantially on the said longitudinal axis, the

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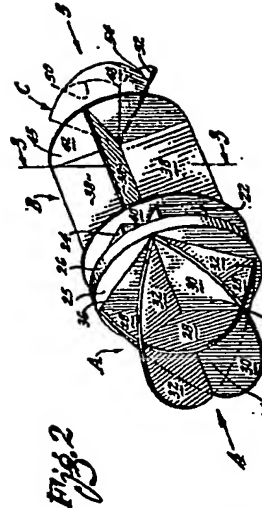
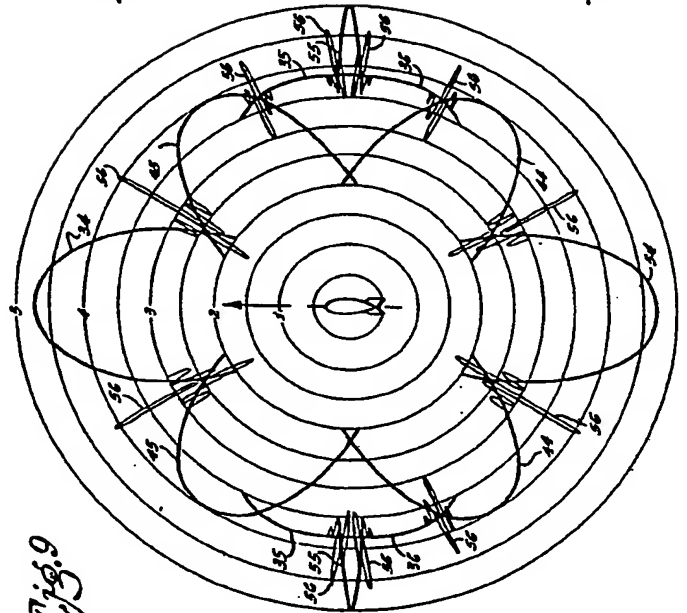
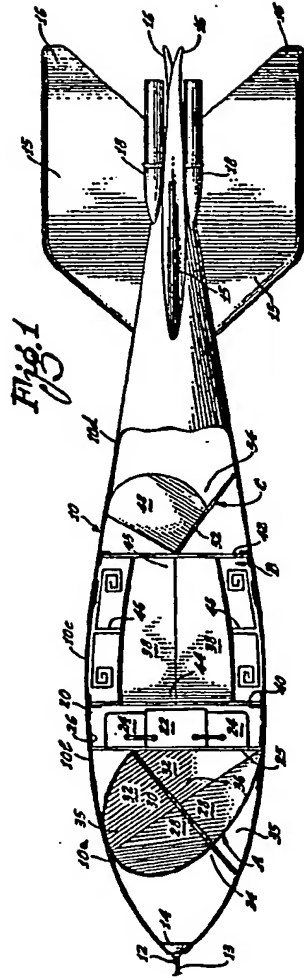




Fig. 6

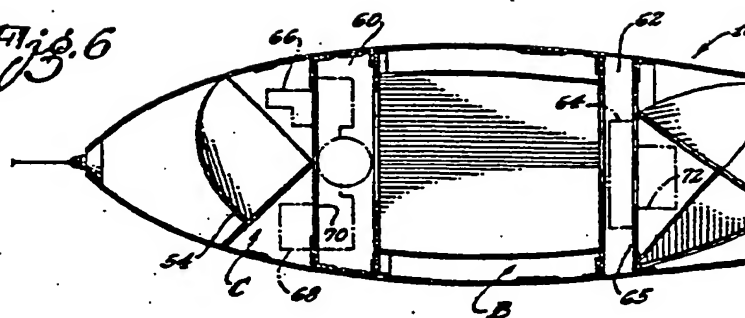


Fig. 7

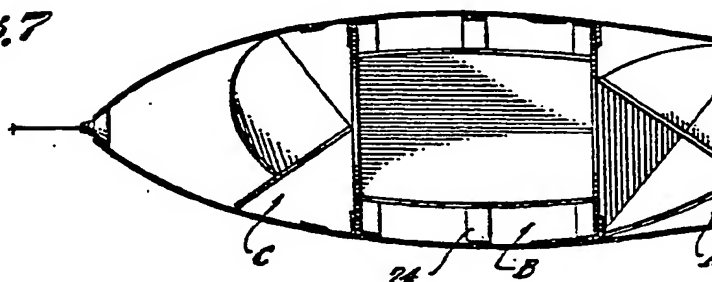


Fig. 5

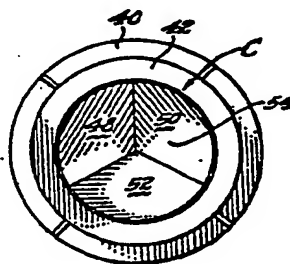
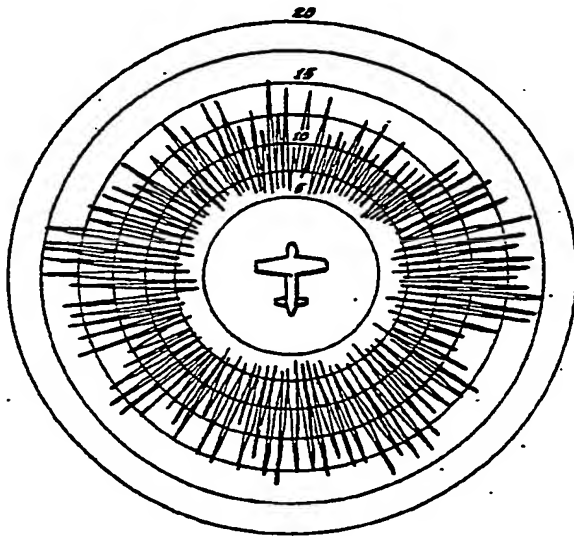
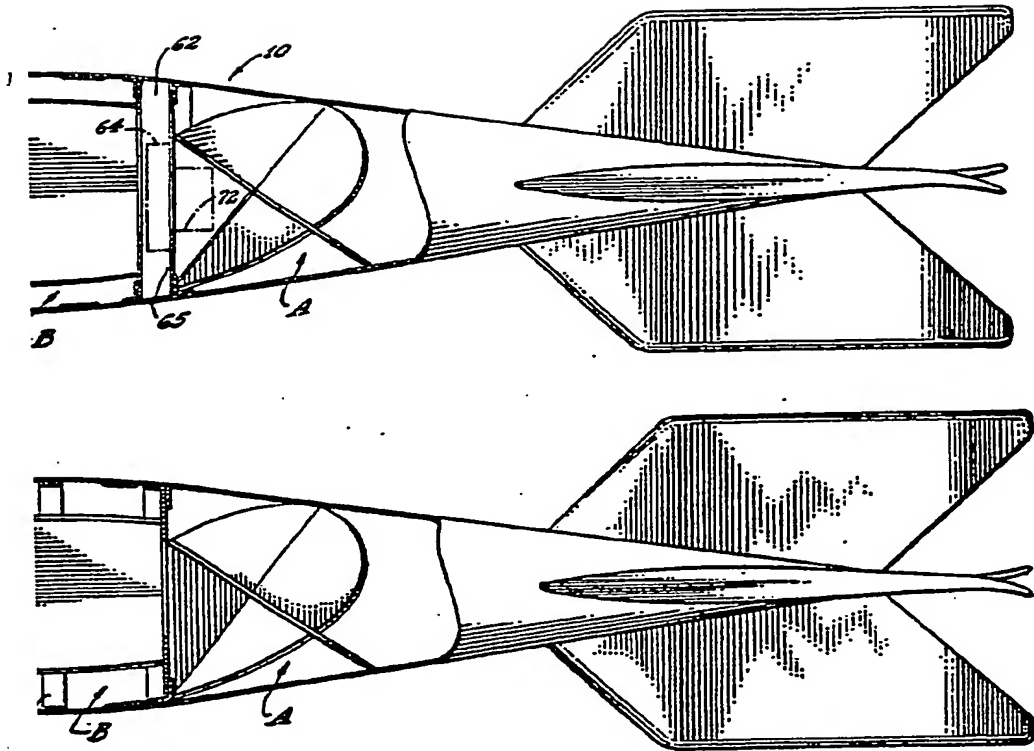
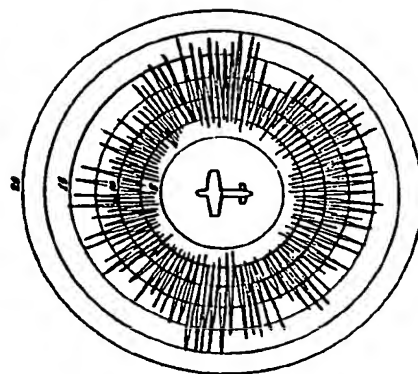
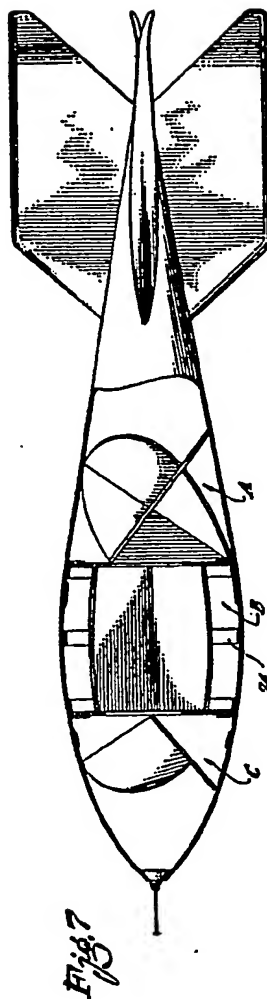
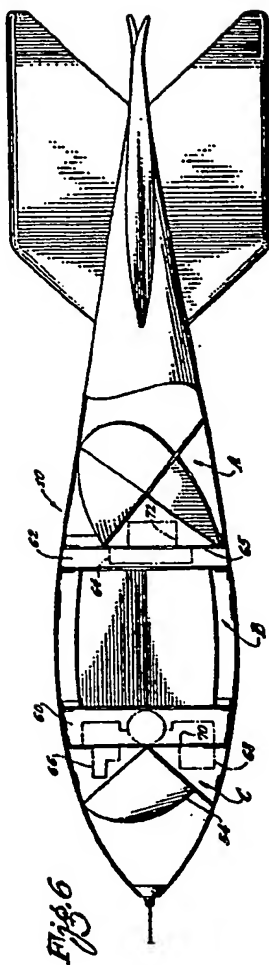


Fig. 8

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the Original on a reduced scale*  
Sheet 2





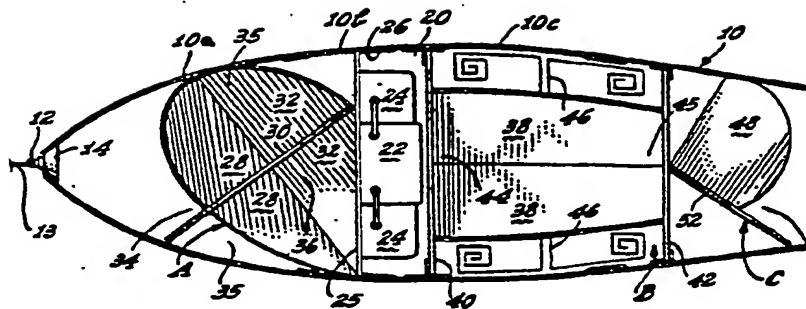


Fig. 9

